REPORT OF

HYDRAULIC MODEL TESTS

OF

NORTHAMPTON PUMPING STATION

CONNECTICUT RIVER

NORTHAMPTON, MASSACHUSETTS

MADE AT THE

ALDEN HYDRAULIC LABORATORY

WORCESTER POLYTECHNIC INSTITUTE

BY

C. M. ALLEN, HYDRAULIC ENGINEER

APRIL 1941

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

U. S. ENGINEER OFFICE PROVIDENCE, R. I.

ALDEN HYDRAULIC LABORATORY
WORCESTER POLYTECHNIC INSTITUTE

Worcester, Mass.

July 3, 1941

Lieutenant Colonel Harley Latson, District Engineer

U. S. Engineer Office

Providence, Rhode Island

Dear Sir:

I submit the following report of tests of the Northampton Pumping Plant Model. The work was carried on during the period from May, 1940 to June, 1941.

Yours very truly,

(Signed) C. M. Allen, Director
Alden Hydraulic Laboratory

Report of Model Tests of

Northampton Pumping Plant

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Report of Model Tests on

NORTHAMPTON PUMPING PLANT

SUMMARY

A wooden model of the Northampton Pumping Plant was constructed 1/10th full size to study the flow conditions. The model comprised the sewer inlet, the gravity conduit, the intake conduit, the lateral spillway and a portion of the overflow conduit.

It was found that with a total inflow of 400 c.f.s. and 300 c.f.s. flowing to the pumps, the lateral spillway discharged 100 c.f.s. within the design limitations, the water level being at elev. 107 at the end of the sewer inlet.

In the original layout, having the sewer inlet in line with the gravity conduit, bad flow conditions were observed in the transition at the end of the sewer intake and around the nose of the dividing pier between the gravity and pump intake conduits. Locating the sewer intake symmetrically between the gravity and pump intake conduits greatly improved the flow conditions. The most rapid wall divergence, consistent with satisfactory hydraulic performance, that could be used in the transition at the end of the sewer intake was found to be 1:5 for each side.

AUTHORITY

These tests were made under authority conveyed by Contracts No. W-699-eng-754 dated May 20, 1939 and No. W-699-eng-1312 dated December 17, 1940 between the United States of America and the Alden Hydraulic Laboratory of the Worcester Polytechnic Institute.

OBJECT

The object of these tests was to determine:

1. The flow conditions in the gravity and intake conduits with the design flow of 400 c.f.s.

2. The elevation of the water surface required to cause the lateral spillway to discharge 100 c.f.s. with 300 c.f.s. flowing to the pumps.

3. The best form of transition at the sewer inlet.

DESCRIPTION OF PROJECT

The Northampton Pumping Station is located in Northampton, Massachusett, at the point where the Northampton Levee crosses the old bed of Mill River. It will be used to discharge storm and sanitary sewage from an area of about 770 acres, including practically the entire city of Northampton, through the levee.

During periods of normal stage on the Connecticut River, any run-off from the area will flow through the gravity conduit into the bed of Mill River downstream from the protection works. When the river stage exceeds 106.0 m.s.l., the gravity conduit will be closed, and the flow will be discharged by the pumps.

The maximum design flow is 400 c.f.s. and the required design capacity of the pumps 300 c.f.s. A lateral spillway and storage pond will be provided to temporarily store water which cannot be discharged immediately by the pumps. To provide a further factor of safety and flexibility of operation, excess pump capacity was installed, making the total capacity 400 c.f.s. at a stage of 119.0 m.s.l. The pumping capacity decreases with increasing river stage, and is 340 c.f.s. with the river at elev. 127.0, the maximum design grade.

Reference is made to Plates Nos. 1, 2, 3, and 4.

DESCRIPTION OF MODEL

A wooden model of the Northampton Pumping Plant was made 1/10th full size according to the designs included as Plates Nos.

3 and 4. It comprised 20 ft. of the sewer intake, the gravity conduit as far as the outlet sluice gate, the intake conduit leading to the pumps, a small portion of the pump sump, the lateral spillway, and 38 ft. of the overflow conduit leading to the storage pond. The top of the model was left open, all of the walls terminating at elev. 111.0.

Water was supplied to the model through a calibrated 8" x 4" Venturi meter which discharged into a head box 8 ft. x 7 ft. 6" in plan. The head box was large enough to insure quiet approach conditions. The water discharged from the head box into the sewer intake conduit which was fitted with a bell mouth entrance to preserve smooth flow conditions.

The discharge from the gravity conduit and pump intake flowed into a weir box in which was located a 90° "V" notch weir. This was used to measure the discharge flowing to the pumps. The discharge over the lateral spillway was then determined by subtracting the weir discharge from the Venturi discharge. The weir was calibrated by comparison with the Venturi meter. A tilting gate was located in the pump sump to adjust the distribution of flow between the lateral spillway and the pump intake.

The overflow conduit was continued for 38 ft. beyond the lateral spillway. For the model test this conduit was laid parallel to the other conduits and discharged upstream. Stop logs, located at the end of this conduit, provided control of the water level.

The discharge of the Venturi meter was measured by means of a differential mercury manometer. The head on the "V" notch weir was measured in a 1" vertical gage glass.

The arrangement of the model is shown in Plate No. 5 and Photos. No. 1, 2 and 3.

COMPUTATION OF PROTOTYPE QUANTITIES

Quantity	Scale Factor	Derivation
Length	10	By definition
Head	10	By definition
Area	100	Since Area = $(\text{Length})^2$
Volume	1000	Since Volume = $(\text{Length})^3$
Velocity	3.16	Since Velocity $= \sqrt{2gH}$
Discharge	316.2	Since Discharge = (Area) (Velocity)
Roughness "n"	1.47	From Manning's Formula for Pipe Roughness

All dimensions and quantities in the text are prototype values

RESULTS

As the plant was originally designed the sewer intake was located on the right side of the structure in line with the gravity conduit. With this arrangement there was a one-sided flare as a transition between the sewer intake and the rack chamber. The model tests showed that the flow never filled this transition resulting in a high velocity stream of water on the right side and a large back eddy on the left. The high velocity stream of water from the sewer intake caused very disturbed flow conditions around the pier nose separating the gravity and pump intake conduits. This was true whether the discharge passed through the gravity conduit or through the pump intake conduit.

Very disturbed flow conditions were found in the pump intake conduit with a flow of 100 c.f.s. passing over the spillway and 300 c.f.s. going to the pump sump. A part of this disturbance was caused by the pier nose and the remainder was due to the high velocities and abrupt changes in section in the pump intake conduit. With 100 c.f.s. passing over the spillway, the water approached the crest at such a small angle that the first 2 ft. of the crest was practically dry. At the other end of the spillway the water had a depth of 1.5 ft. Water surface profiles for various flow conditions with the model as originally designed are presented in Plate No. 7. These flow conditions are also shown in Photos. No. 4 and 5.

MODIFICATIONS TO MODEL

As may be seen in Photo No. 5, the upstream end of the spillway is relatively ineffective. Undoubtedly, the length of the spillway could be reduced several feet if this change were desirable. No test data were taken of the effect of such changes.

An effort was made to improve the flow in the pump intake conduit by making the flow slope down more gradually in the hope of gradually decelerating the velocities in this conduit. To this end a bottom filler piece was installed which changed the bottom slope from 1 on 3.1 to 1 on 7.1. Water surface profiles, included as Plate No. 8, show that this change caused no appreciable effect upon the flow conditions.

At this point in the tests, the upstream end of the model was rebuilt locating the sewer intake halfway between the gravity and the pump intake conduits. This made possible a symmetrical transition at the end of the sewer intake. Each side wall diverged 1:5 from the centerline of the conduit. This arrangement of the model is shown in Photos No. 6 and 7.

The modification of the model improved the flow conditions with all combinations of discharge. The water now followed the flare, there being no back eddies. Since the flow followed the transition, the water velocities in the rack chamber were materially reduced and more uniformly distributed. This, in turn, reduced the disturbed flow condition at the pier nose between the gravity and the pump intake conduits. Naturally, some of this improvement was reflected in the flow conditions in the pump intake conduit with water passing over the lateral spillway. However, the flow in this region was still quite disturbed as may be seen in Photos. No. 8 and 9. Flow conditions in the gravity conduit are shown in Photos. No. 10 and 11. Water surface profiles for these test conditions are shown in Plate No. 9.

An effort was made to make the transition shorter by increasing the divergence of the side walls. Divergences of 1:3, 1:4 and 1:4.5 were tested but side eddies were found in all of them. The reason for the long tapering transition in this case apparently lies in the fact that the draft immediately downstream from the transition is always one-sided, whether the gravity conduit or the pump intake is in use. Thus a transition having very stable flow conditions is required if consistent flow conditions are to be maintained.

GENERAL COMMENTS

The accuracy of the construction of the model and of the measurements was estimated as follows. When originally constructed, all dimensions were reproduced within 1/32" in the model which corresponds to 5/16" full size. After being in use for some time it was found that the model dimensions were within 1/8" of their true values which corresponds to 1-1/4" full sizo. The water surface profiles were measured with a surveyor's level and a ruler. It is believed that the elevations so measured were within 1" (full size) of their true values.

The discharge was measured with a calibrated 8" x 4" Venturi meter. It is estimated that the discharge measurements were within 2% of their true values.

The test work was carried on under the direct supervision of Prof. L. J. Hooper of the Alden Hydraulic Laboratory staff. Mr. John A. Hamer, Junior Engineer, represented the U. S. Engineer Office, Providence, Rhode Island, during the tests.

The model tests were made in connection with the preparation of plans for Connecticut River Flood Control which at the time of the tests was under the general supervision of Lt. Col. J. S. Bragdon, District Engineer and is now under Lt. Col. Harley Latson, District Engineer; and Mr. T. S. Burns, Chief of Engineering Division. Close cooperation was maintained with the laboratory by Mr. J. B. Drisko, head of the Hydraulics and Reports Section.

CONCLUSIONS

These model tests of the Northampton Pumping Plant showed that:

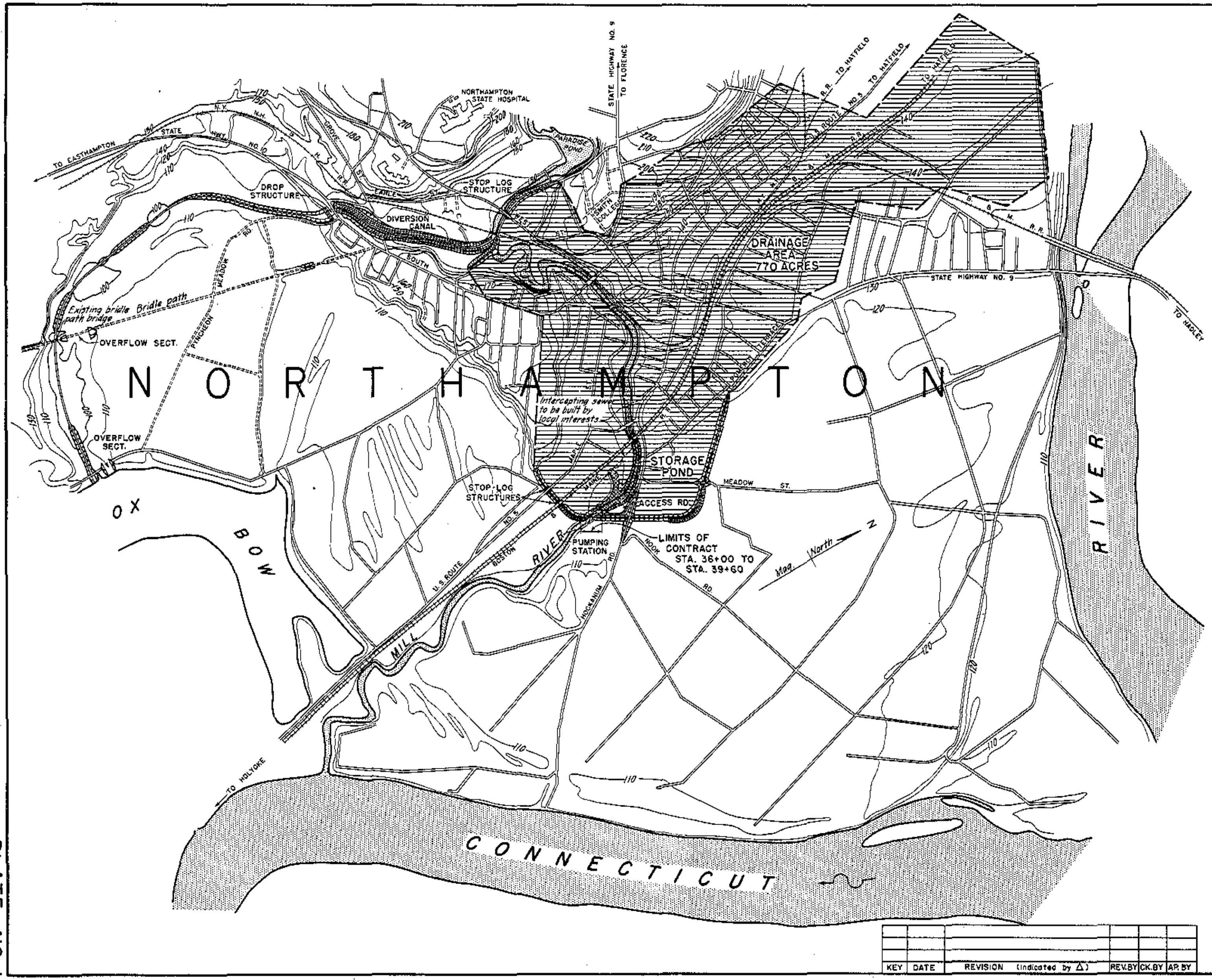
1. The flow conditions, while rough, were acceptable.
2. The lateral spillway discharged 100 c.f.s. with 300 c.f.s. flowing to the pumps within the design requirements.
3. A symmetrical transition at the end of the sewer intake materially improved the flow conditions.

Respectfully submitted,

(Signed) C. M. Allen
Alden Hydraulic Laboratory

WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY



CONNECTICUT RIVER FLOOD CONTROL

NORTHAMPTON PUMPING STATION

DRAINAGE AREA PLAN

CONNECTICUT RIVER — MASSACHUSETTS

IN 7 SHEETS — SCALE: 1 IN = 800 FT. — SHEET NO. 6

U.S. ENGINEER OFFICE, PROVIDENCE, R.I. — JAN. 1940

SUBMITTED: SENIOR ENGINEER, HEAD, DESIGN SECTION — APPROVAL RECOMMENDED: PRINCIPAL ENGINEER, CHIEF, F.C. ENGINEERING DIV. — APPROVED: LT. COL. CORPS OF ENGINEERS, DISTRICT ENGINEER

DESIGNED: P.C. Hanscomb, ASST. ENGINEER — DRAWN: W.K.D. TRACED: W.E.L. CHECKED: W.T.R.

FISCAL YEAR 1940

FILE NO. CT-4-2067

KEY	DATE	REVISION (Indicated by △)	REV.BY	CK.BY	AP.BY

N.4

PLATE NO. I

WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY

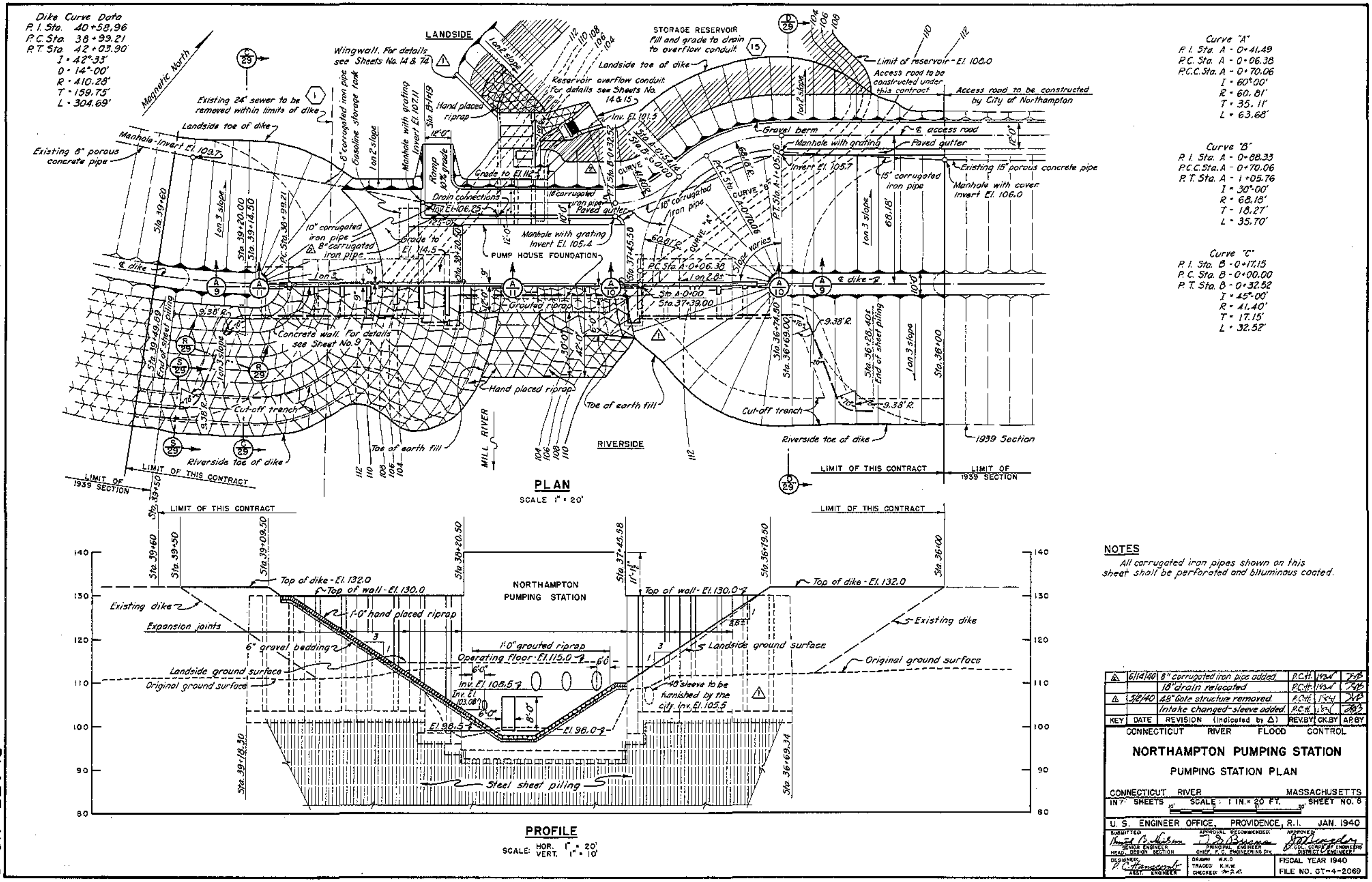
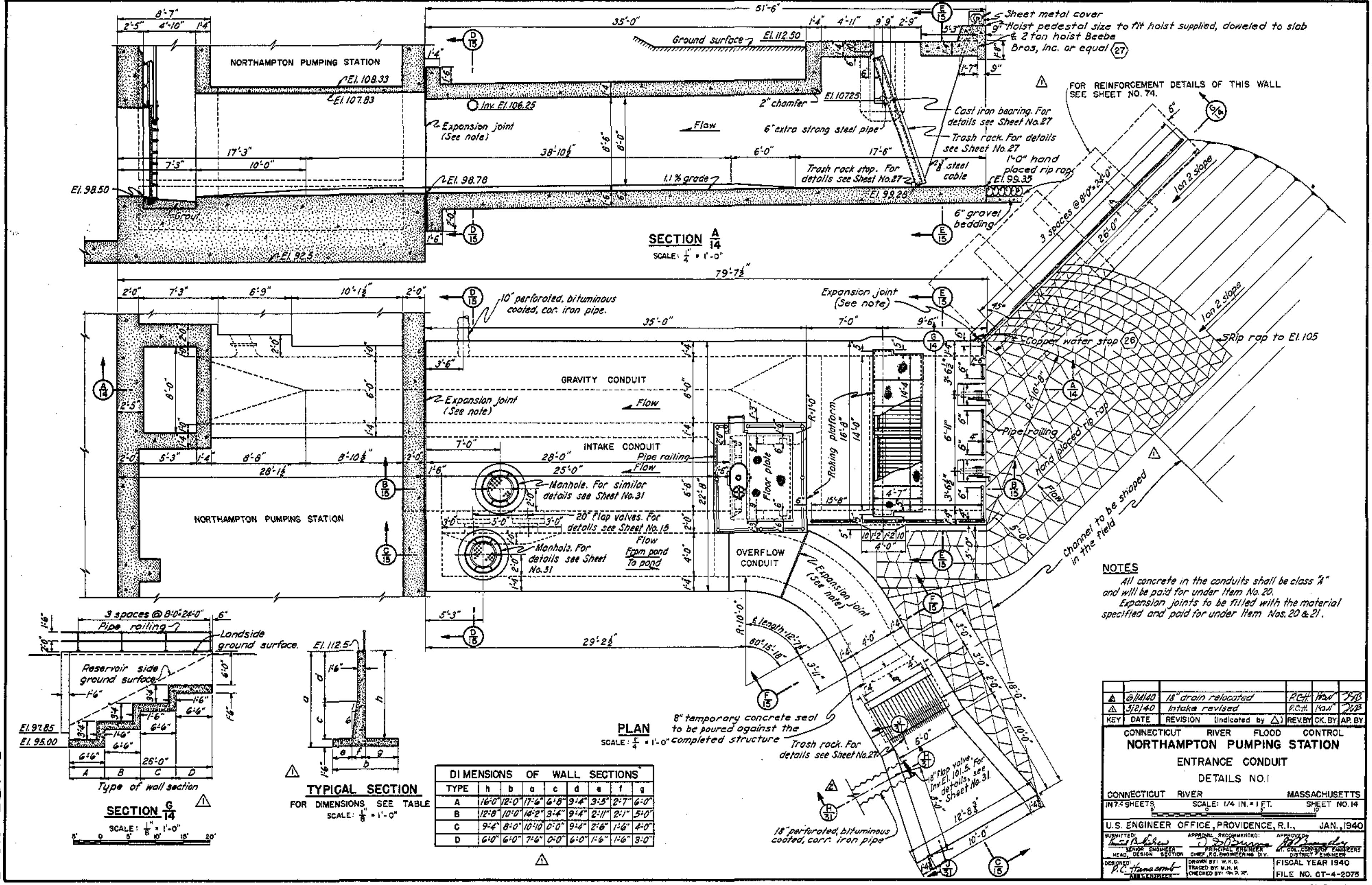


PLATE NO. 2

N.4



NOTES

All concrete in the conduits shall be class "A" and will be paid for under Item No. 20.

Expansion joints to be filled with the material specified and paid for under Item Nos. 20 & 21.

DIMENSIONS OF WALL SECTIONS								
TYPE	h	b	a	c	d	e	f	g
A	16'-0"	12'-0"	17'-6"	6'-8"	9'-4"	3'-5"	2'-7"	6'-0"
B	12'-8"	10'-0"	14'-2"	3'-4"	9'-4"	2'-11"	2'-1"	5'-0"
C	9'-4"	8'-0"	10'-10"	0'-0"	9'-4"	2'-6"	1'-6"	4'-0"
D	6'-0"	6'-0"	7'-6"	0'-0"	6'-0"	1'-6"	1'-6"	3'-0"

KEY	DATE	REVISION (Indicated by △)	REV. BY	CK. BY	AP. BY
2	6/14/40	18" drain relocated	P.C.H.	H.W.	J.J.B.
1	3/2/40	Intake revised	P.C.H.	H.W.	J.J.B.

CONNECTICUT RIVER FLOOD CONTROL

NORTHAMPTON PUMPING STATION

ENTRANCE CONDUIT

DETAILS NO. 1

CONNECTICUT RIVER MASSACHUSETTS

IN 74 SHEETS SCALE: 1/4 IN. = 1 FT. SHEET NO. 14

U.S. ENGINEER OFFICE, PROVIDENCE, R.I., JAN., 1940

SUBMITTED: SENIOR ENGINEER, HEAD, DESIGN SECTION

APPROVAL RECOMMENDED: PRINCIPAL ENGINEER, CHIEF, F.C. ENGINEERING DIV.

APPROVED: LT. COL., CORPS OF ENGINEERS, DISTRICT ENGINEER

DESIGNED: P.C. Hanscomb, ASST. ENGINEER

DRAWN BY: W.K.D.
TRACED BY: M.H.M.
CHECKED BY: M.P.F.

FISCAL YEAR 1940

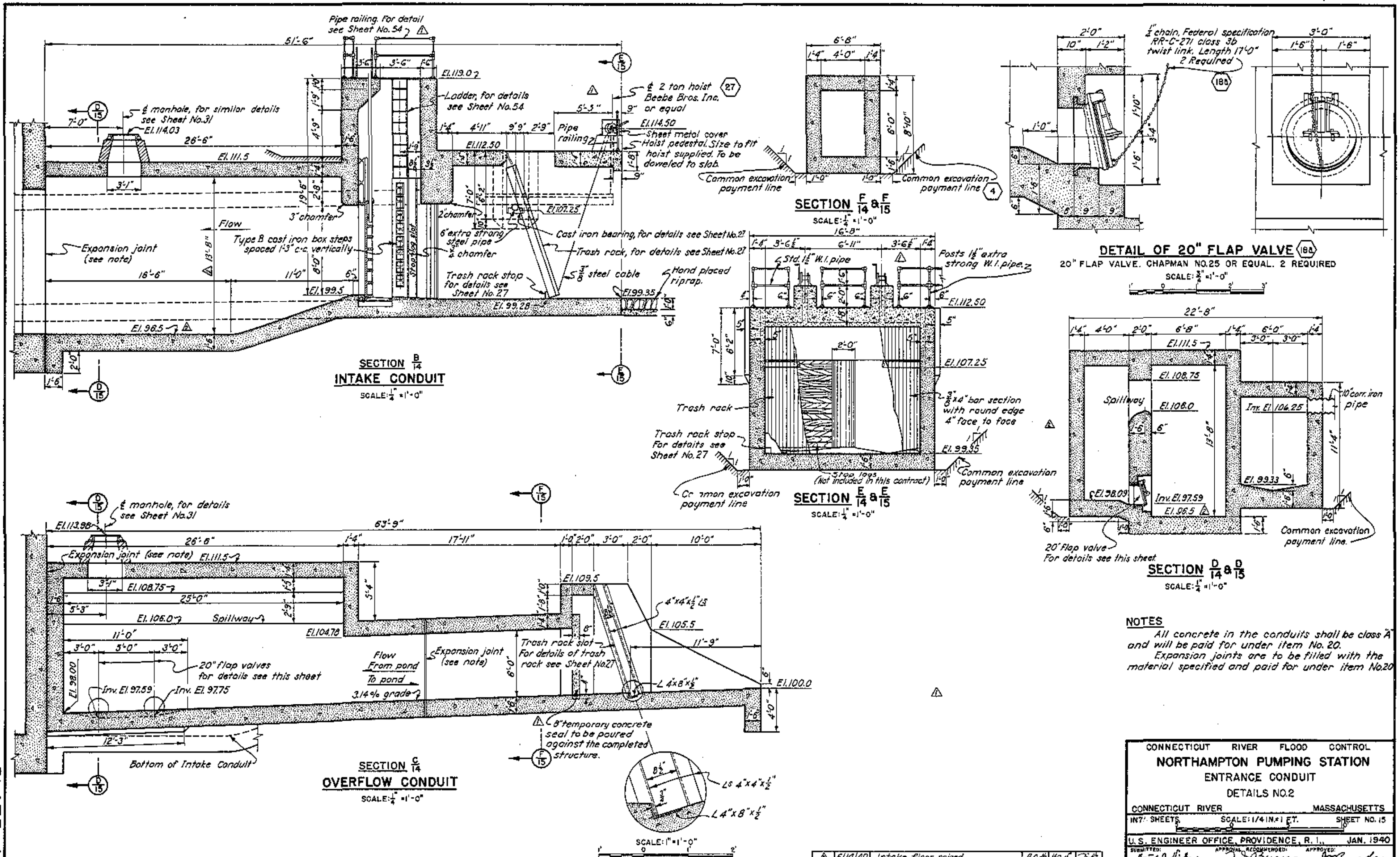
FILE NO. CT-4-2075

N.4

PLATE NO. 3

WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY



NOTES

All concrete in the conduits shall be class "A" and will be paid for under item No. 20.

Expansion joints are to be filled with the material specified and paid for under item No. 20.

KEY	DATE	REVISION (Indicated by △)	REV.BY	CK.BY	AP.BY
△	6/14/40	Intake floor raised	P.C.H.		
		18" Drain Relocated	P.C.H.		
△	5/2/40	Intake revised-Sec. A/14 removed	P.C.H.		

CONNECTICUT RIVER FLOOD CONTROL

NORTHAMPTON PUMPING STATION

ENTRANCE CONDUIT

DETAILS NO.2

CONNECTICUT RIVER — MASSACHUSETTS

IN 7/ SHEETS — SCALE: 1/4 IN. = 1 FT. — SHEET NO. 15

U.S. ENGINEER OFFICE, PROVIDENCE, R.I., JAN. 1940

SUBMITTED: SENIOR ENGINEER, HEAD, DESIGN SECTION — APPROVAL RECOMMENDED: PRINCIPAL ENGINEER, CHIEF, F.C. ENGINEERING DIV. — APPROVED: LT. COL., CORPS OF ENGINEERS, DISTRICT ENGINEER

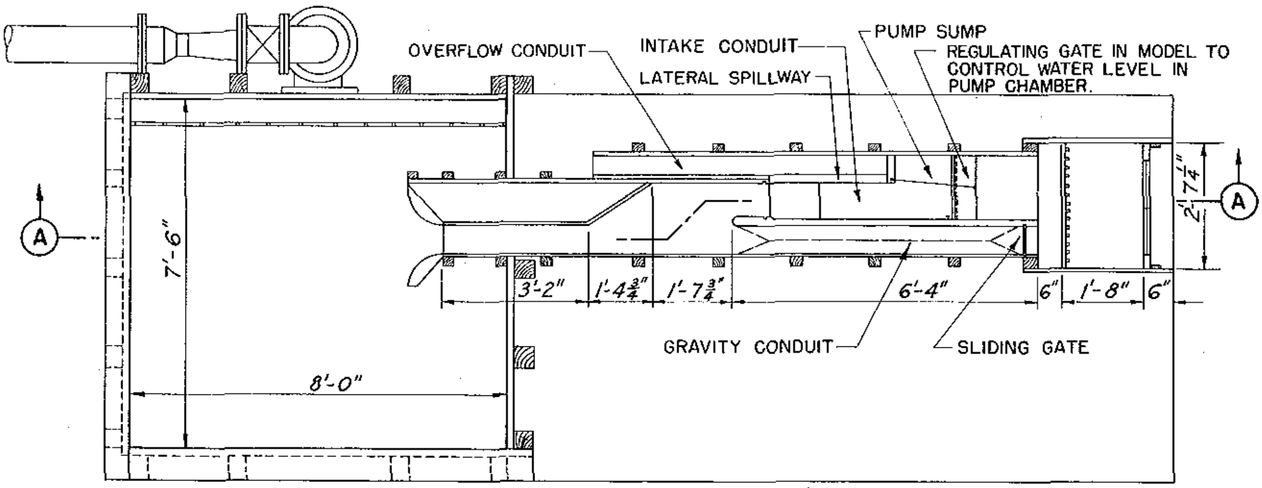
DESIGNED: P. C. Hanscomb, ASS'T. ENGINEER — DRAWN: W.K.D. & H.S.H. TRACED: H.A.V. CHECKED:

FISCAL YEAR 1940

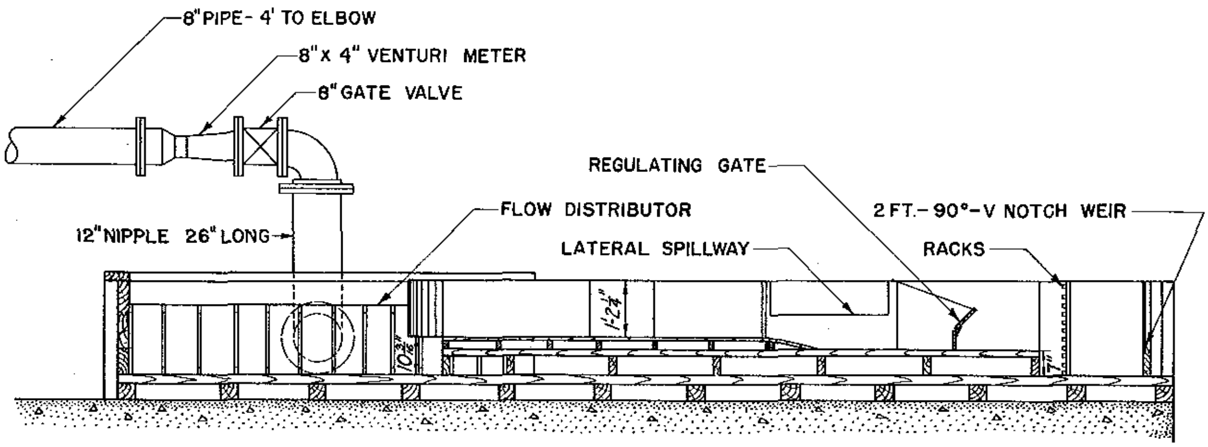
FILE NO. CT-4-2076

N. 4

PLATE NO. 4



GENERAL PLAN



LONGITUDINAL SECTION A-A

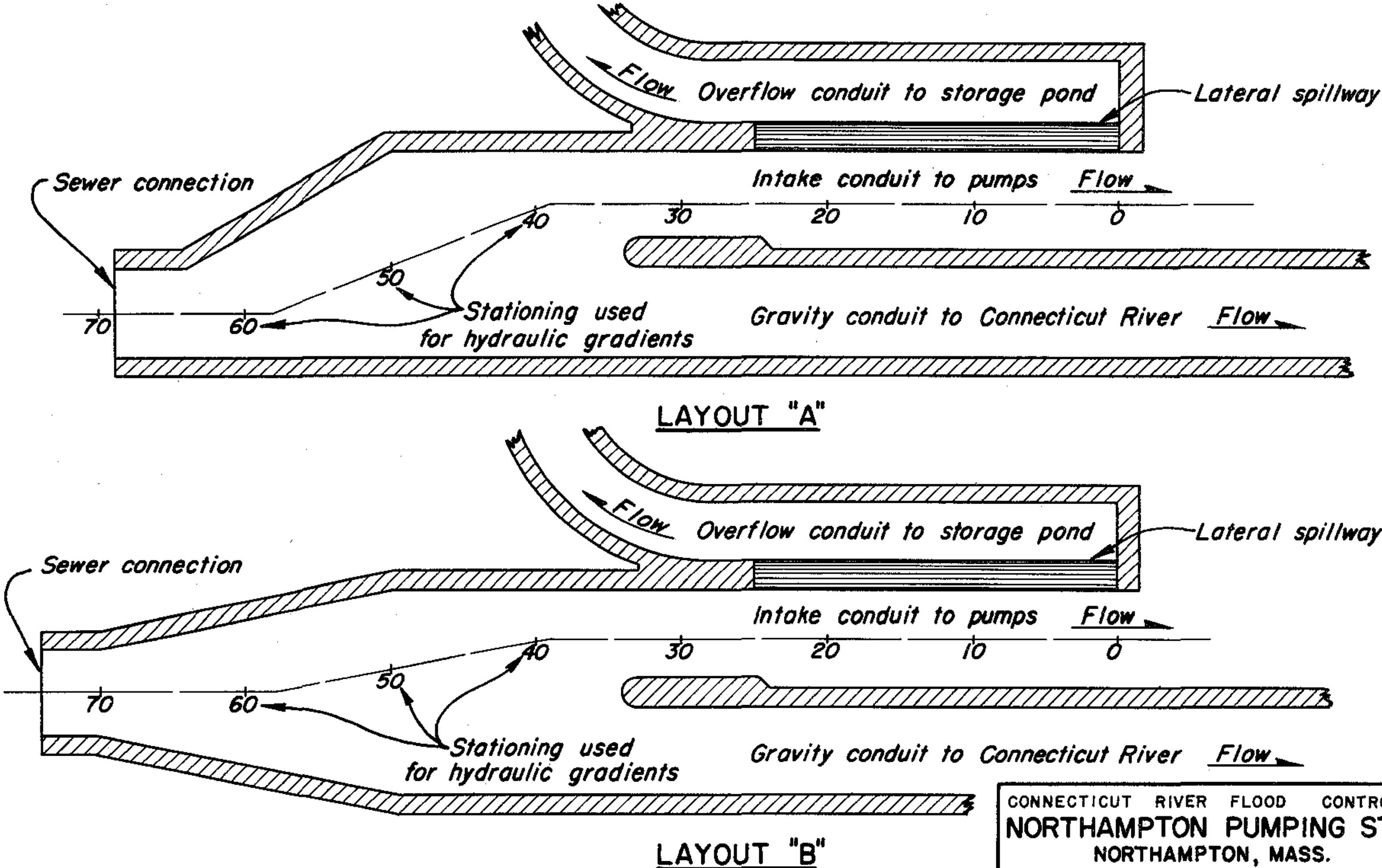
TESTS AT

ALDEN HYDRAULIC LABORATORY

WORCESTER POLYTECHNIC INSTITUTE

CONNECTICUT RIVER FLOOD CONTROL		
NORTHAMPTON PUMPING STATION GENERAL PLAN AND SECTION MODEL RATIO 1:10		
CONNECTICUT RIVER		MASSACHUSETTS
SCALE 1" = 2'-0"		
U.S. ENGINEER OFFICE,		PROVIDENCE, R.I.
APRIL 1941		CT-3-1207

PLATE NO. 5



MODEL RATIO 1 : 10

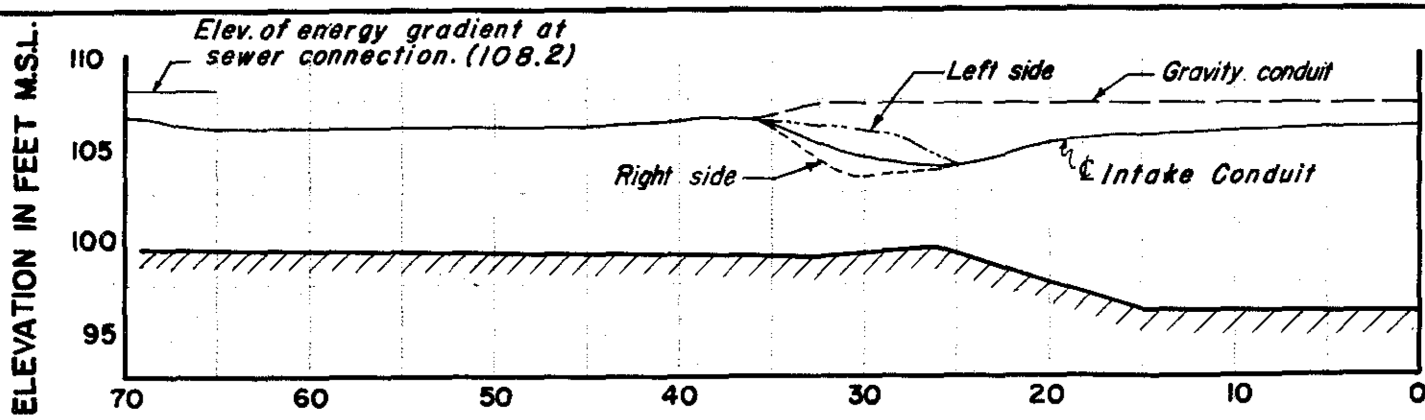
TESTS AT
ALDEN HYDRAULIC LABORATORY
WORCESTER POLYTECHNIC INSTITUTE

CONNECTICUT RIVER FLOOD CONTROL
NORTHAMPTON PUMPING STA.
NORTHAMPTON, MASS.
PLANS OF ALTERNATE
INLET LAYOUTS
SCALE: 1"= 10'

U.S. ENGINEER OFFICE PROVIDENCE, R.I.

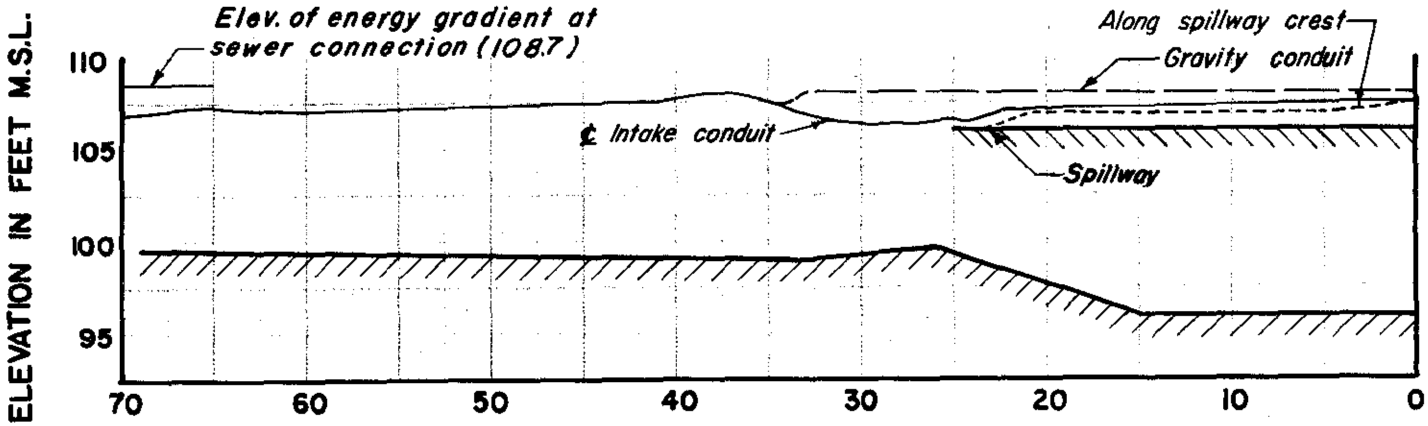
APRIL 1941

PLATE NO. 6



STATIONING IN FEET FROM DOWNSTREAM END OF SPILLWAY

400 C.F.S. TO PUMPS



STATIONING IN FEET FROM DOWNSTREAM END OF SPILLWAY

300 C.F.S. TO PUMPS   100 C.F.S. OVER SPILLWAY

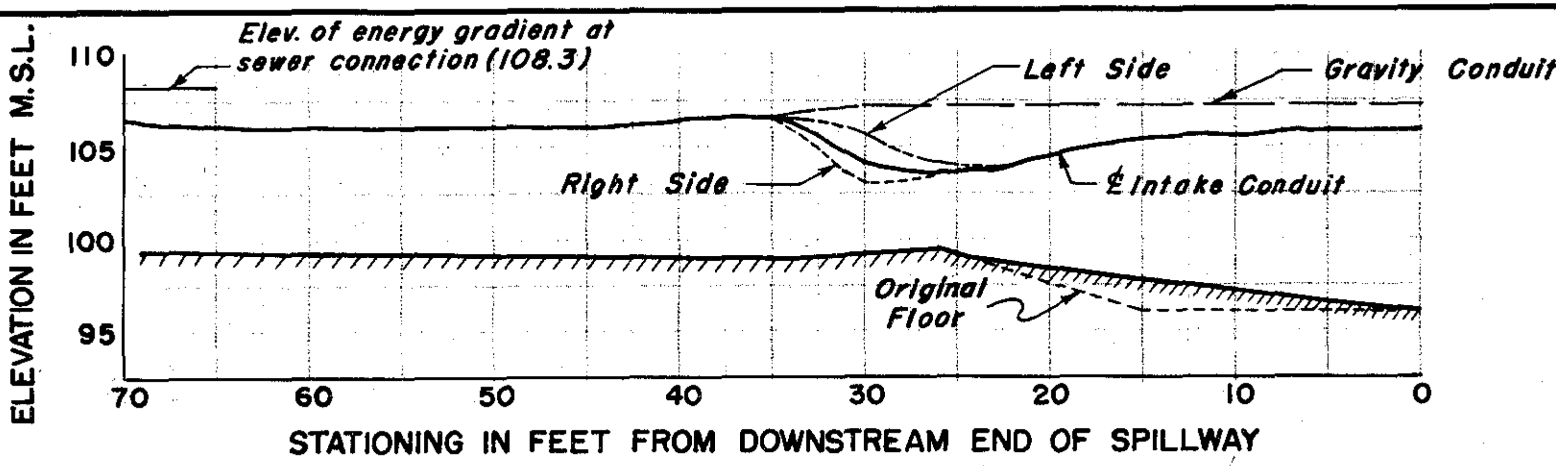
MODEL RATIO 1:10

NOTE:
See plate No.6 for stationing

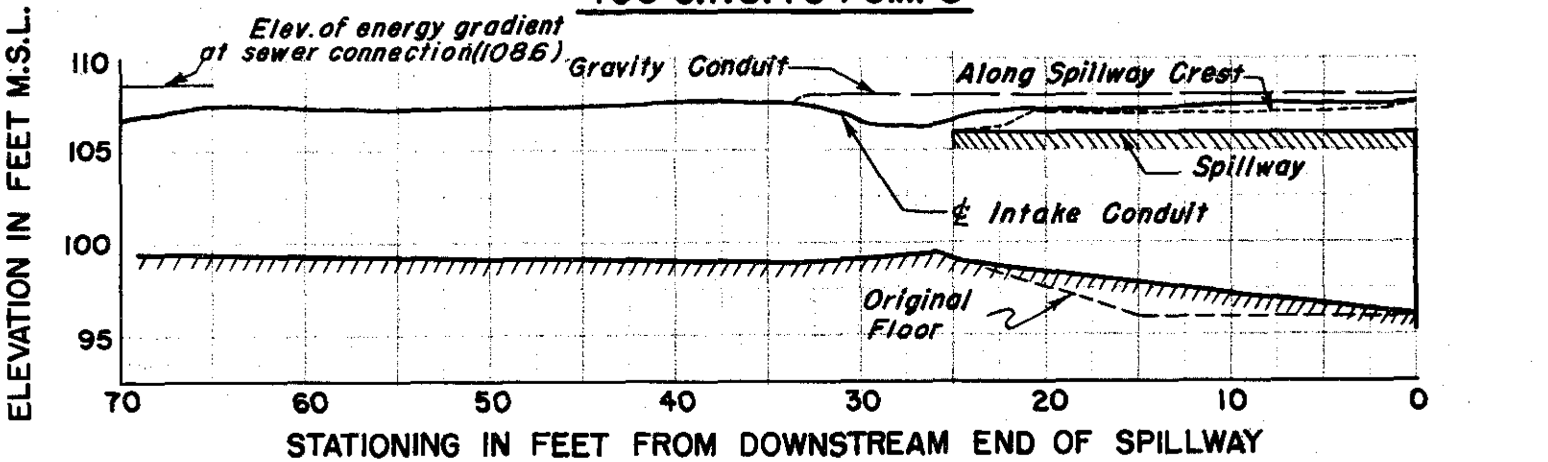
TESTS AT
ALDEN HYDRAULIC LABORATORY
WORCESTER POLYTECHNIC INSTITUTE

CONNECTICUT RIVER FLOOD CONTROL NORTHAMPTON PUMPING STATION NORTHAMPTON MASS. HYDRAULIC GRADIENTS THROUGH THE INTAKE CONDUIT LAYOUT "A"
U.S. ENGINEER OFFICE PROVIDENCE, R. I.
APRIL 1941

PLATE NO. 7



400 C.F.S. TO PUMPS



300 C.F.S. TO PUMPS 100 C.F.S. OVER SPILLWAY

NOTE:

The slope of the floor of the Intake Conduit from Sta. 24.5 to Sta. 0.0 is more gradual than in the original design.
See plate No. 6 for stationing.

MODEL RATIO 1:10

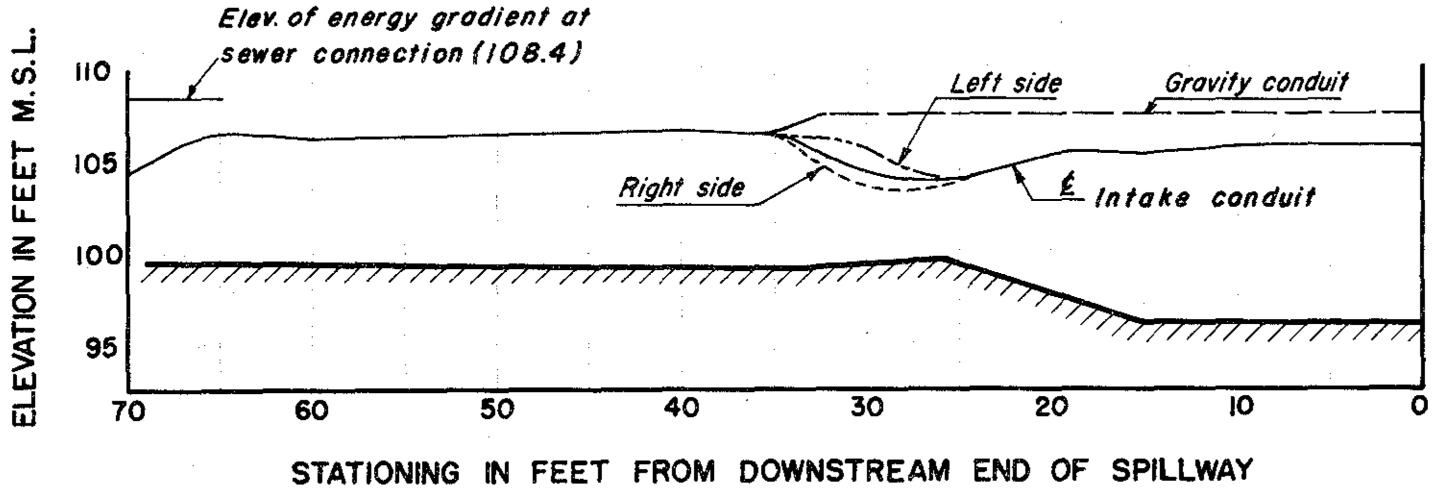
TESTS AT
ALDEN HYDRAULIC LABORATORY
WORCESTER POLYTECHNIC INSTITUTE

CONNECTICUT RIVER FLOOD CONTROL
NORTHAMPTON PUMPING STATION
NORTHAMPTON, MASS.
HYDRAULIC GRADIENTS THROUGH THE INTAKE CONDUIT
LAYOUT "A"

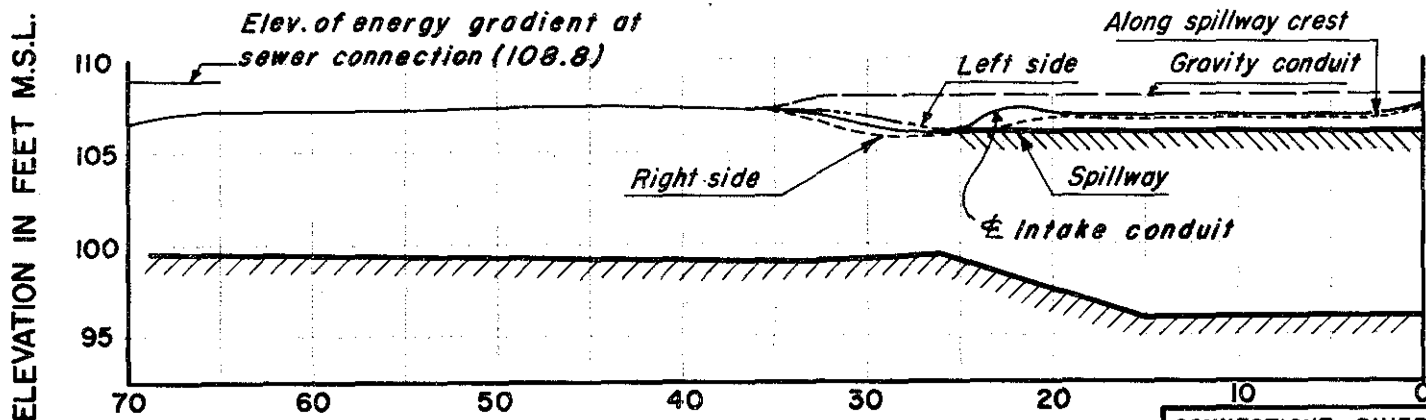
U.S. ENGINEER OFFICE, PROVIDENCE, R.I.

APRIL 1941

PLATE NO. 8



400 C.F.S. TO PUMPS



STATIONING IN FEET FROM DOWNSTREAM END OF SPILLWAY

300 C.F.S. TO PUMPS 100 C.F.S. OVER SPILLWAY

MODEL RATIO 1:10

NOTE:
See plate No. 6 for stationing.

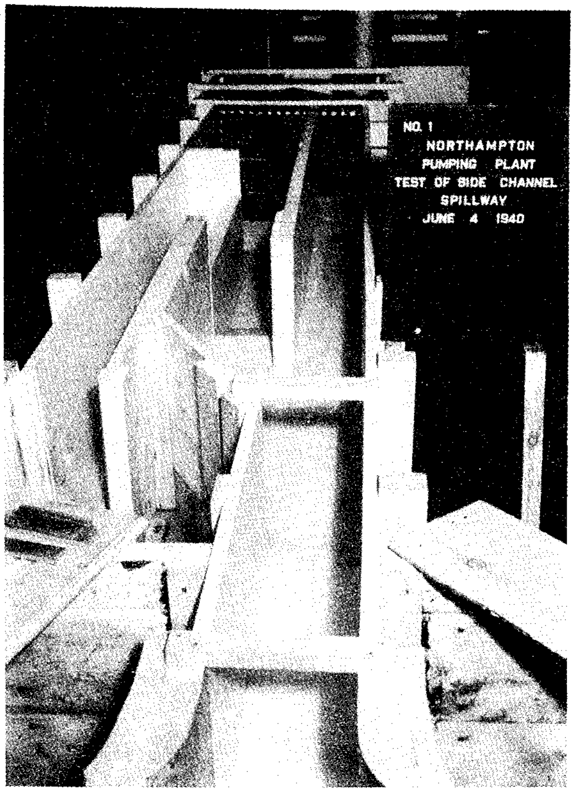
TESTS AT
ALDEN HYDRAULIC LABORATORY
WORCESTER POLYTECHNIC INSTITUTE

CONNECTICUT RIVER FLOOD CONTROL
NORTHAMPTON PUMPING STATION
NORTHAMPTON MASS.
HYDRAULIC GRADIENTS THROUGH THE INTAKE CONDUIT
LAYOUT "B"

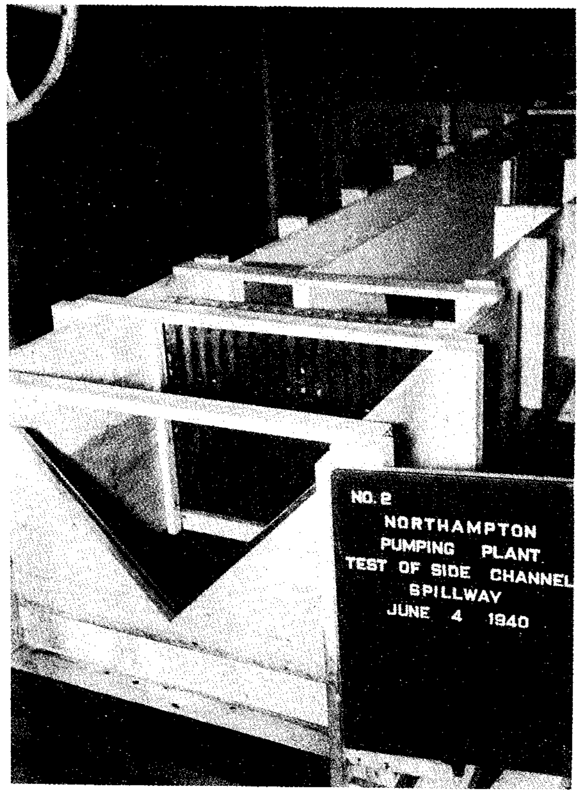
U.S. ENGINEER OFFICE - PROVIDENCE, R. I.

APRIL 1941

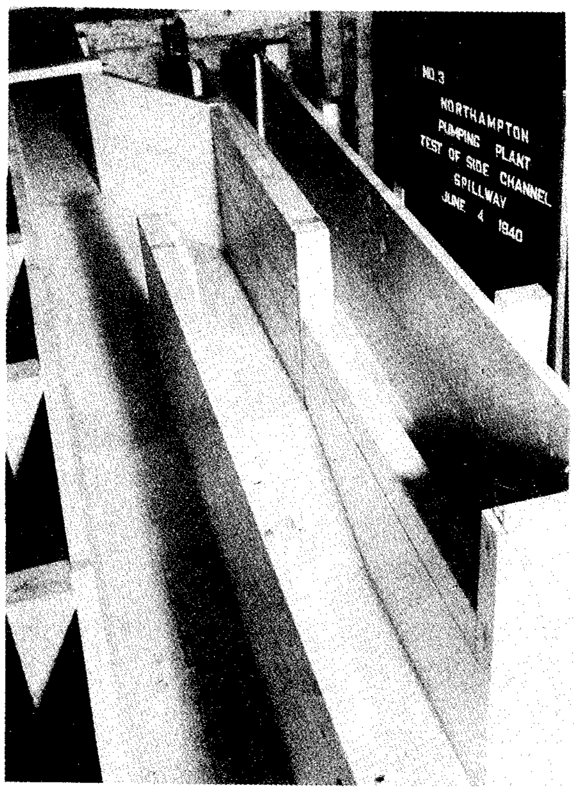
PLATE NO. 9



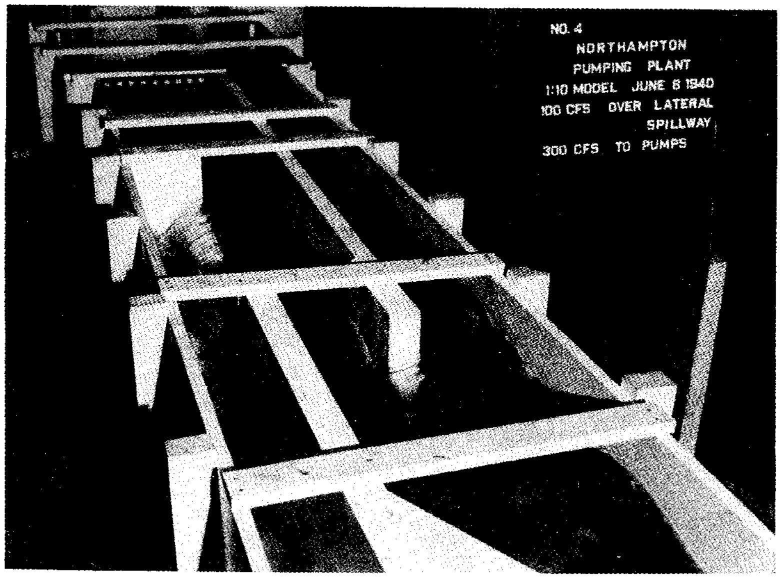
Dry View of Model



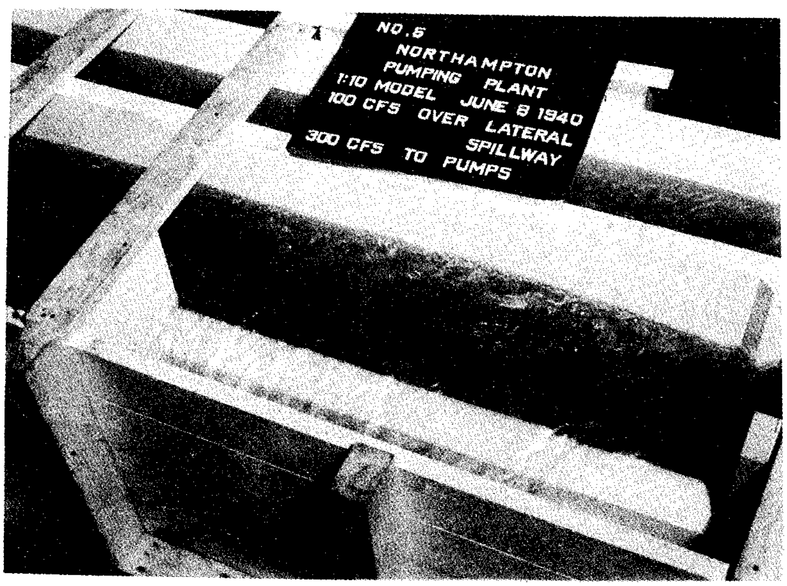
"V" Notch Weir



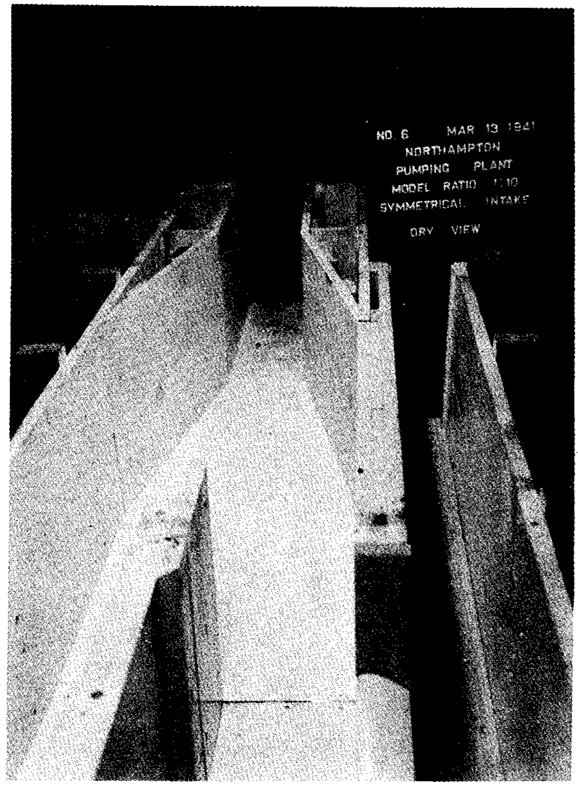
Dry View of Original
Model Looking Upstream



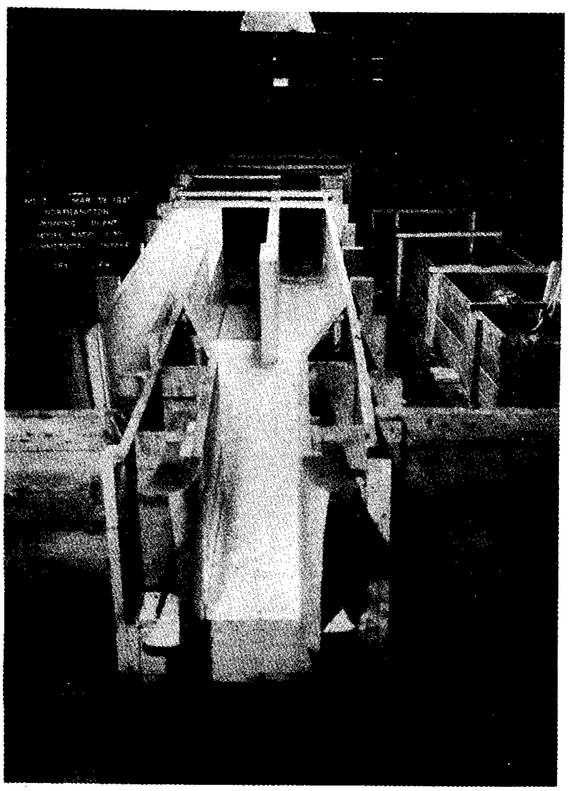
Flow Conditions with Original Design



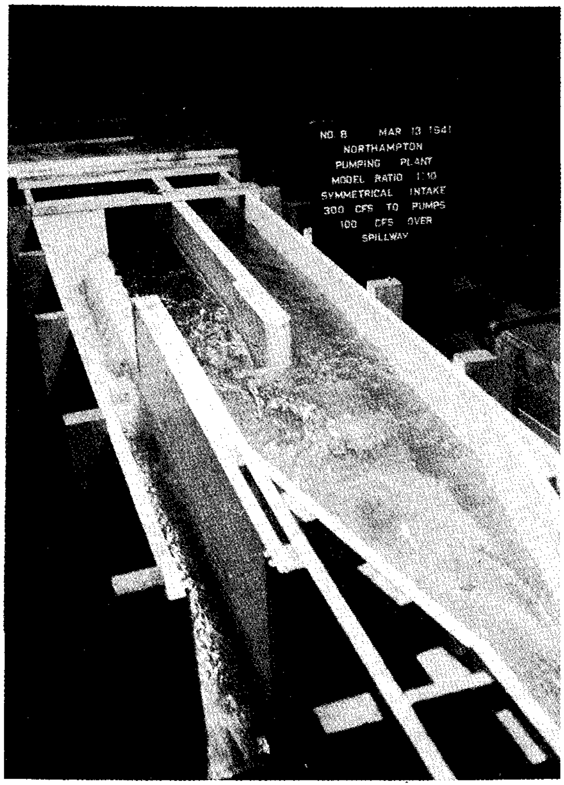
Flow over Lateral Spillway. Original Design



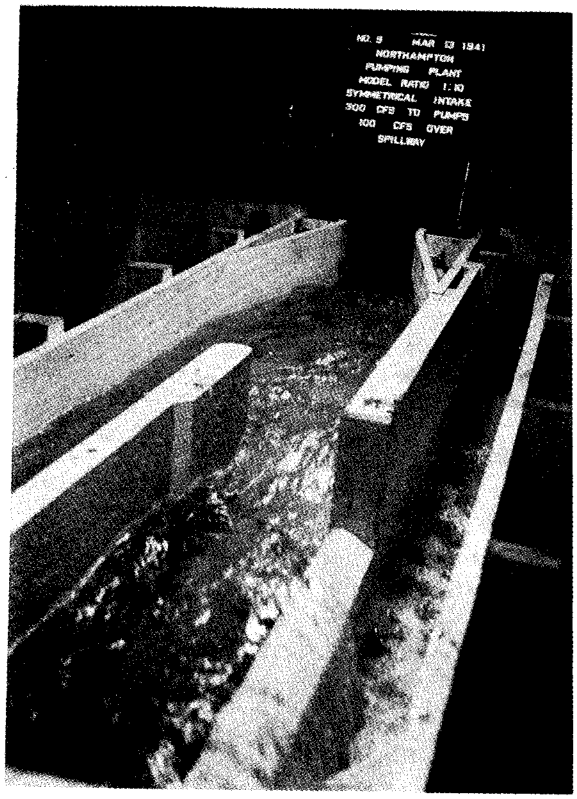
Model with Symmetrical Intake



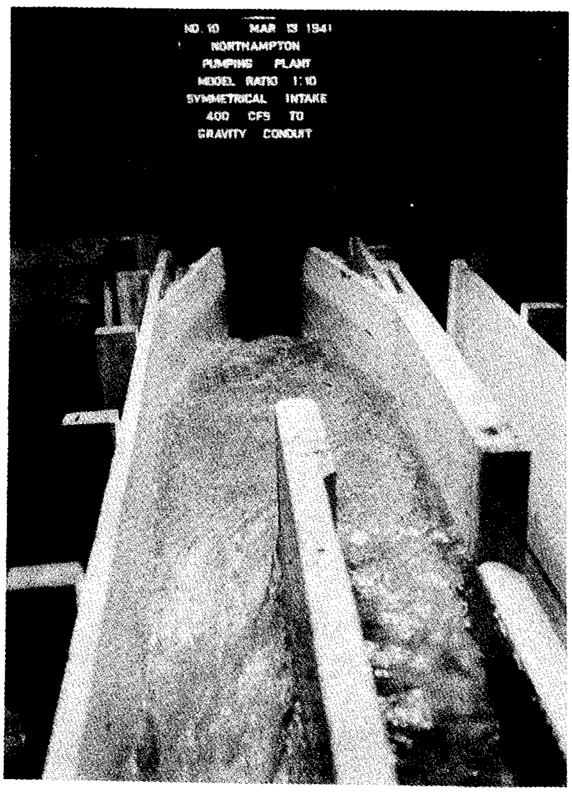
Dry View of Model
Symmetrical Intake



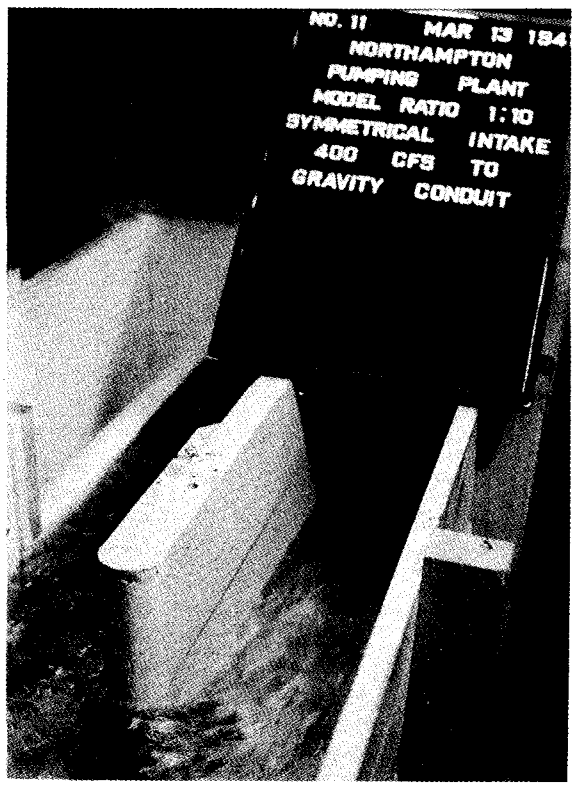
Flow Conditions with
Symmetrical Intake
Looking Downstream



Detail of Flow over Lateral
Spillway Symmetrical Intake



Flow in Symmet-
rical Transition



Flow Around Pier Nose